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(54) **FAST AUTOMATIC GAIN CONTROL FOR HIGH PERFORMANCE WIRELESS COMMUNICATIONS IN SUBSTATION AUTOMATION**

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H03G 3/30 (2006.01)
H04L 27/26 (2006.01)

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CPC ***H03G 3/3036*** (2013.01); ***H04L 27/2601*** (2013.01); *H03G 2201/103* (2013.01)

(58) **Field of Classification Search**
CPC H03G 3/3052; H03G 3/3068; H04L 27/3809; H04L 27/261; H04W 52/52
(Continued)

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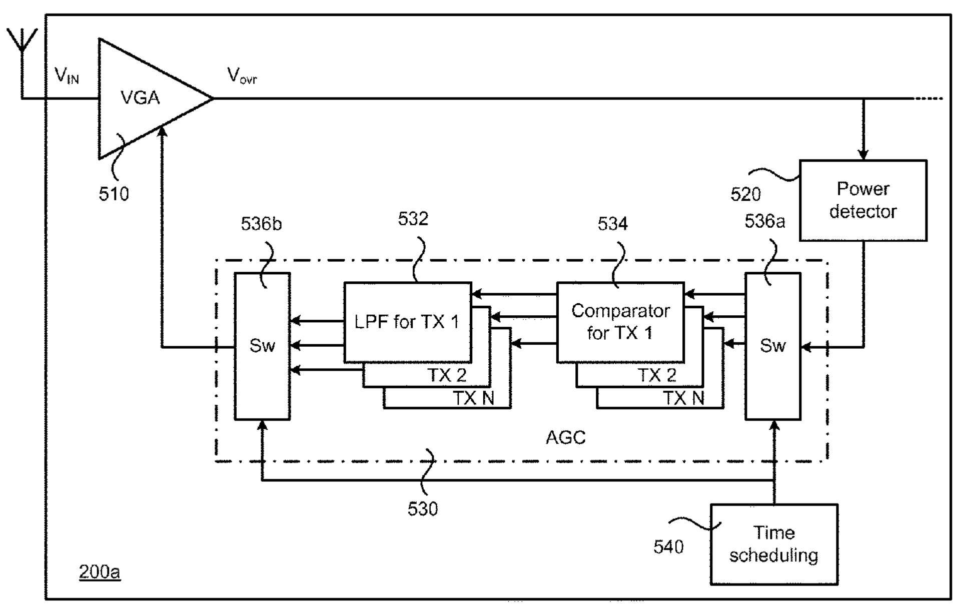
(57) **ABSTRACT**

There is provided mechanisms for automatic gain control in a wireless communication network for power grid control. The wireless communication network employs time based scheduling of packets. A method is performed by a packet receiver in the wireless communication network. The method comprises receiving a packet from a packet transmitter. The packet comprises a preamble. The preamble is composed of a single OFDM symbol. The preamble is represented by a sequence of samples. The method comprises applying automatic gain control to the sequence of samples after variable gain amplitude control has been applied to the sequence of samples. The automatic gain control involves applying an LPF to the sequence of automatic gain controlled samples. The LPF is selected from a bank of LPSs. Which LPF to apply depends on, according to the time based scheduling, from which packet transmitter the packet is received.

20 Claims, 6 Drawing Sheets



(58) **Field of Classification Search**
USPC 375/260, 345, 347
See application file for complete search history.

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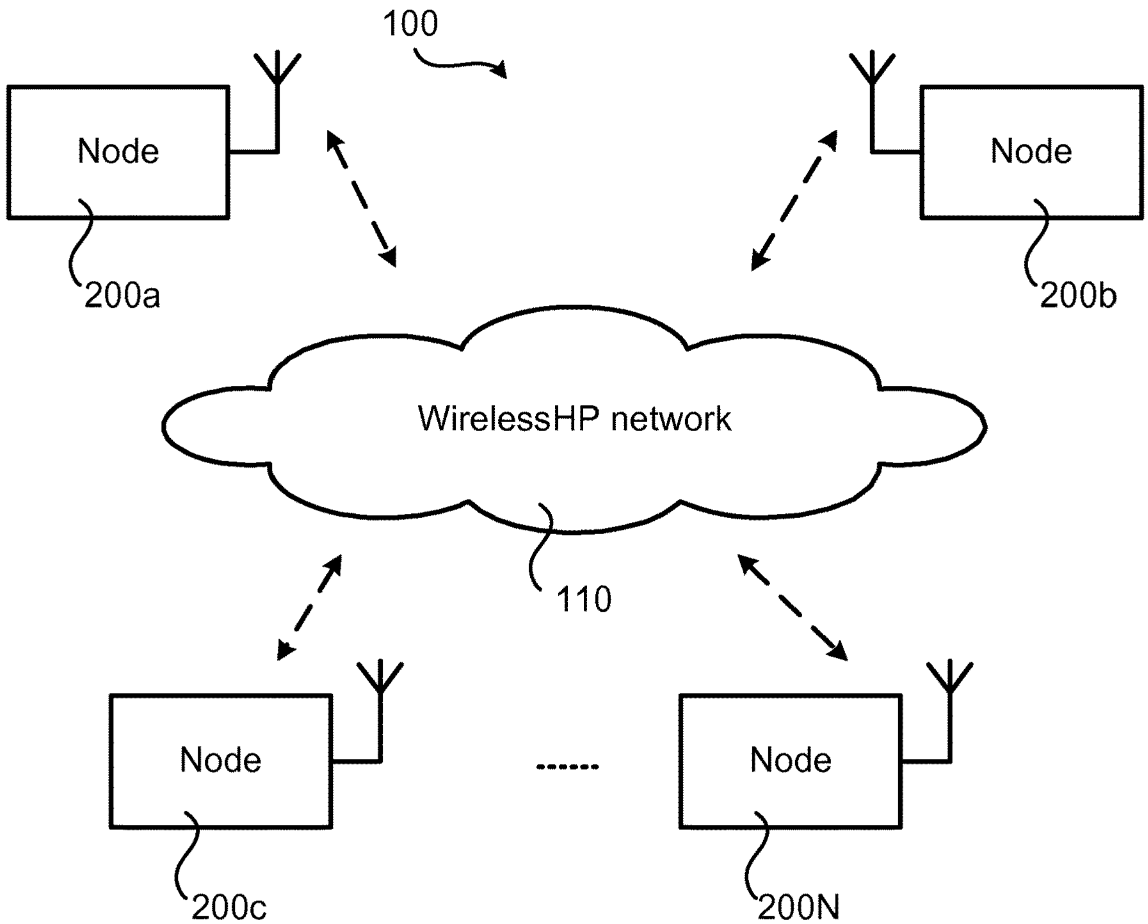
100
Node
200a
Node
200b
WirelessHP network
110
Node
200c

Node
200N

Fig. 1

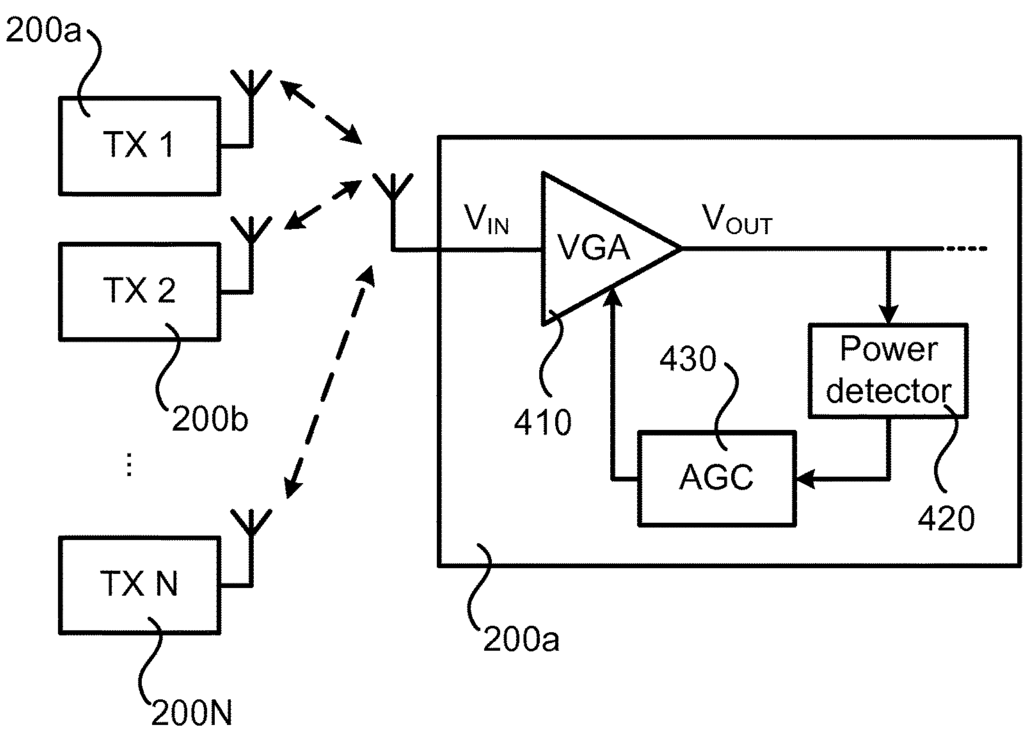
200a
TX 1
TX 2
200b
TX N
200N
V_IN
VGA
V_OUT
410
430
Power detector
AGC
420
200a

Fig. 2

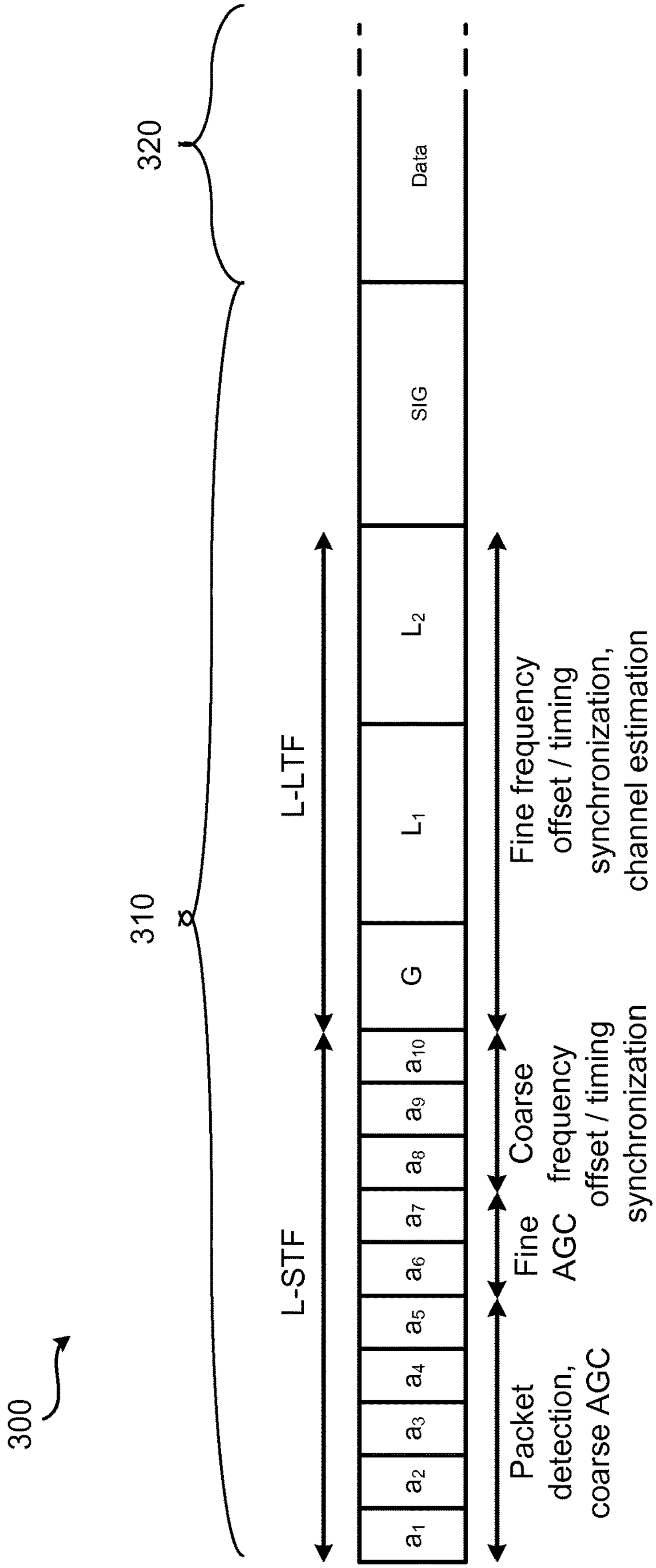
300
310
320
L-STF
L-LTF
a1
a2
a3
a4
a5
a6
a7
a8
a9
a10
G
L1
L2
SIG
Data
Packet detection, coarse AGC
Fine AGC
Coarse frequency offset / timing synchronization
Fine frequency offset / timing synchronization, channel estimation

Fig. 3

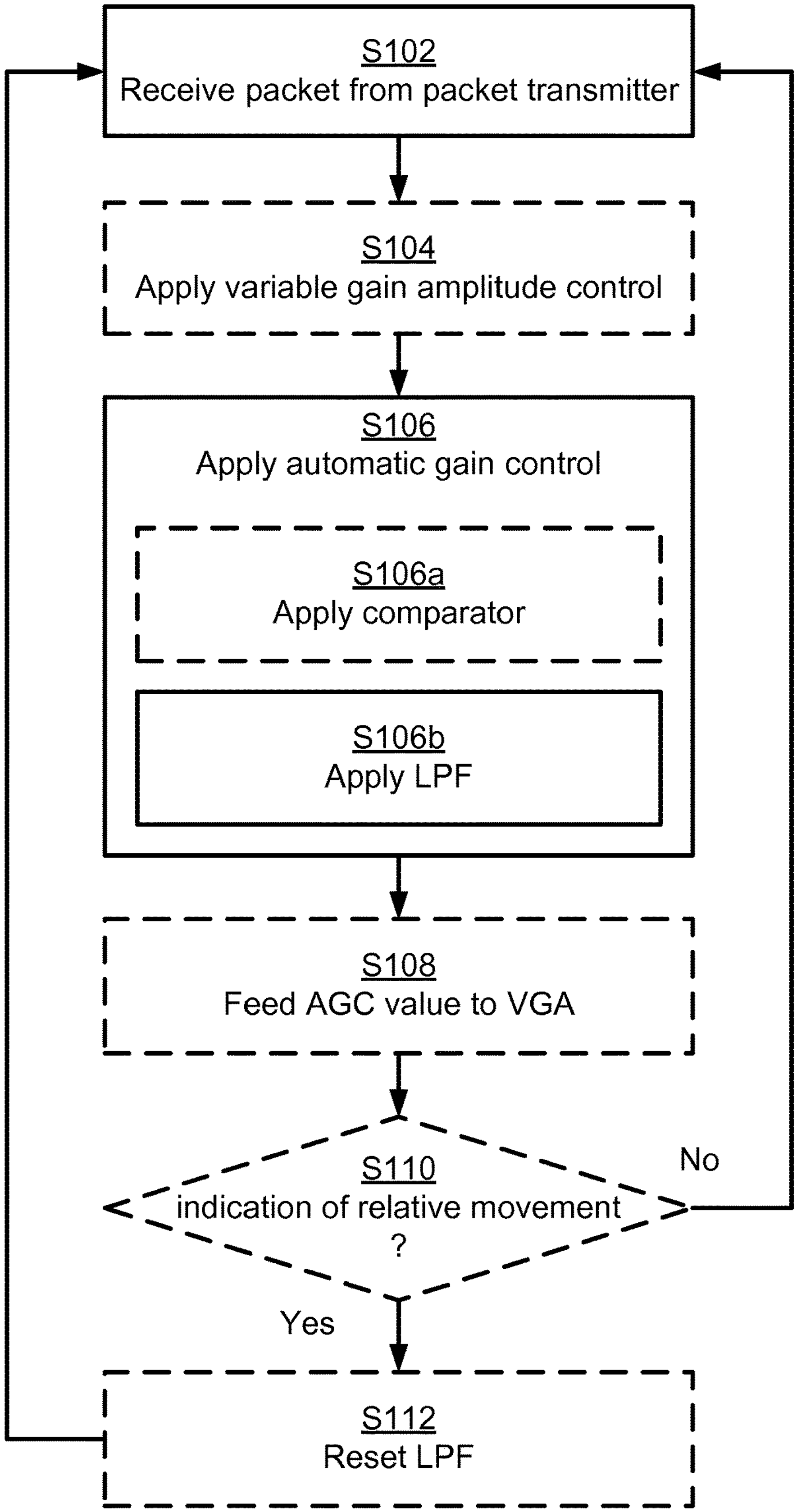
S102
Receive packet from packet transmitter
S104
Apply variable gain amplitude control
S106
Apply automatic gain control
S106a
Apply comparator
S106b
Apply LPF
S108
Feed AGC value to VGA
S110
indication of relative movement
?
No
Yes
S112
Reset LPF

Fig. 4

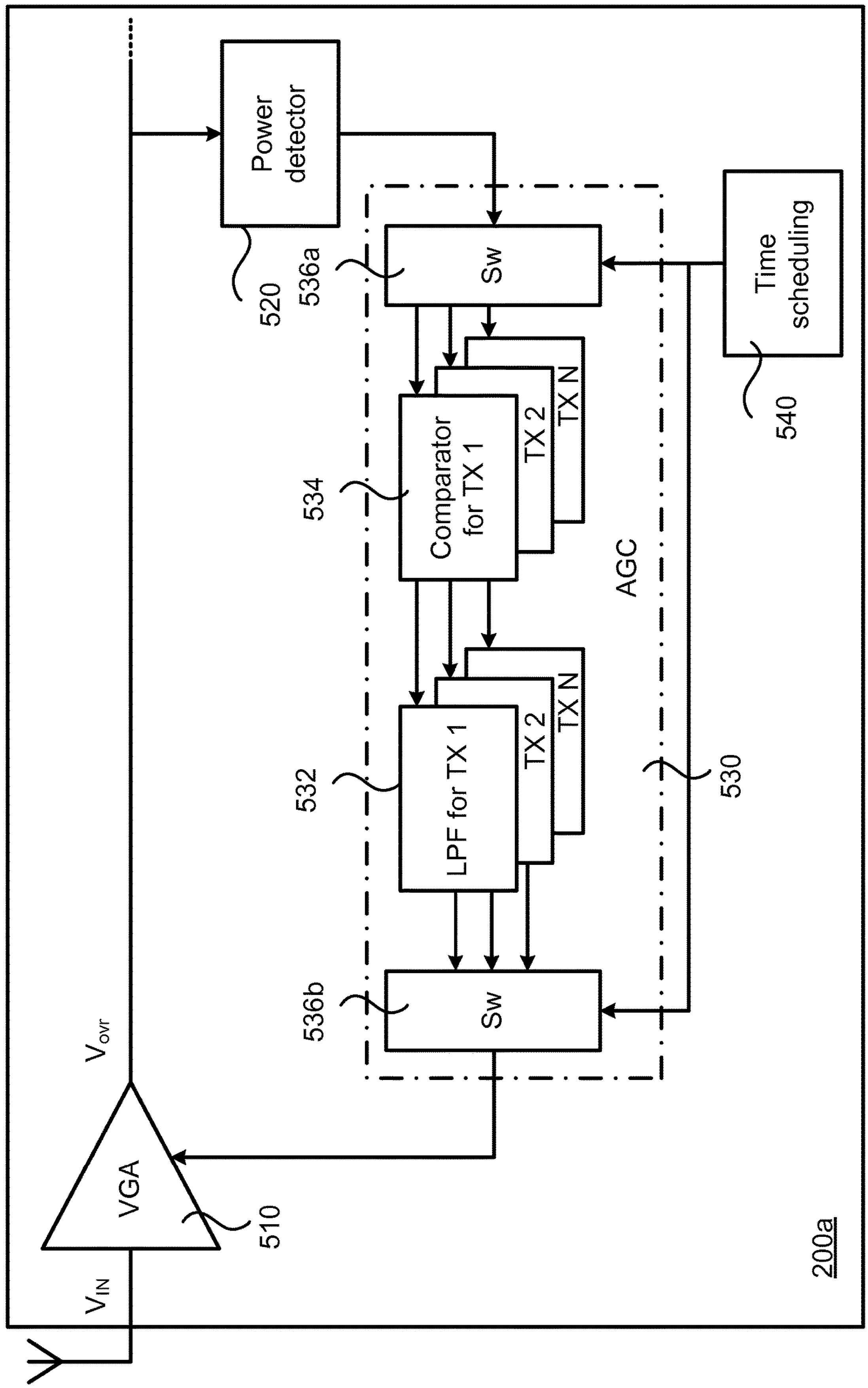
Power detector
520
Sw
536a
Time scheduling
540
Comparator for TX 1
TX 2
TX N
534
AGC
LPF for TX 1
TX 2
TX N
532
530
Sw
536b
V_{ovr}
VGA
510
V_{IN}
200a

Fig. 5

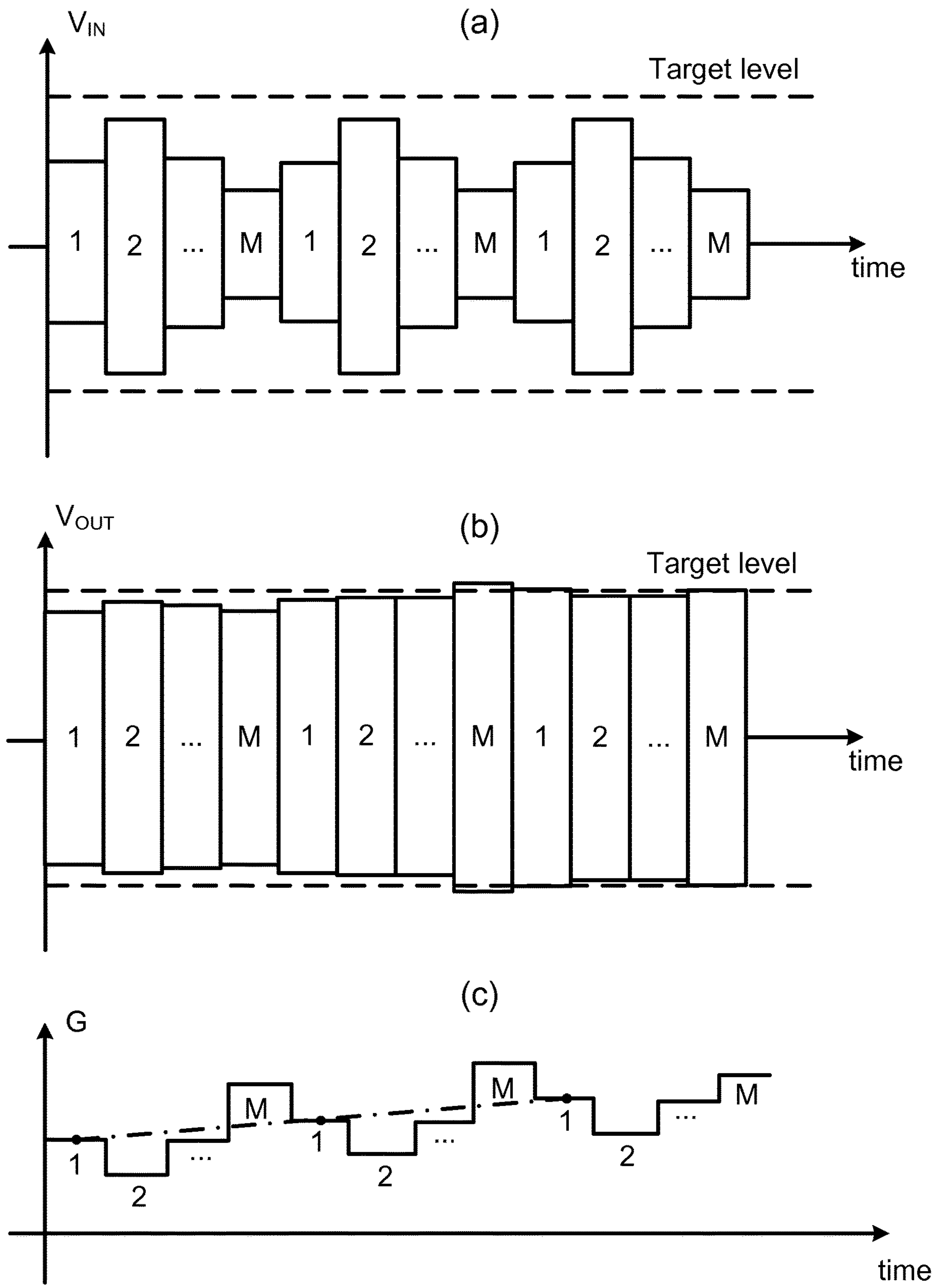
(a)
V_IN
Target level
1
2
...
M
1
2
...
M
1
2
...
M
time
(b)
V_OUT
Target level
1
2
...
M
1
2
...
M
1
2
...
M
time
(c)
G
1
2
...
M
1
2
...
M
1
2
...
M
time

Fig. 6

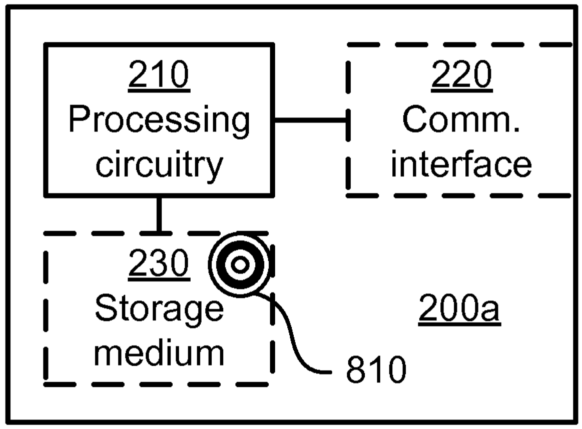
210
Processing circuitry
220
Comm. interface
230
Storage medium
810
200a

Fig. 7

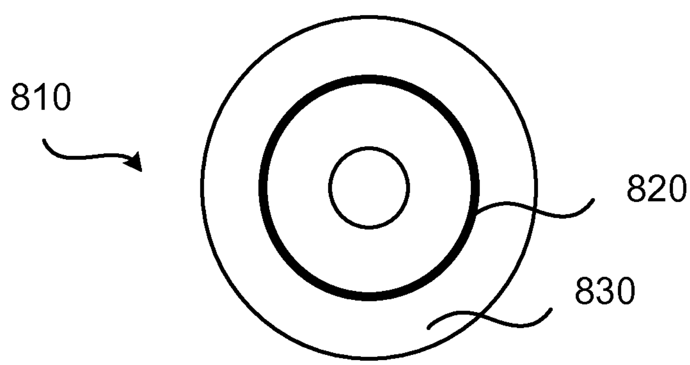
810
820
830

Fig. 8

FAST AUTOMATIC GAIN CONTROL FOR HIGH PERFORMANCE WIRELESS COMMUNICATIONS IN SUBSTATION AUTOMATION

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a national phase application of International Application No. PCT/EP2018/053527, filed on Feb. 13, 2018, which application is incorporated herein by reference.

TECHNICAL FIELD

Embodiments presented herein relate to a method, a packet receiver, a computer program, and a computer program product for automatic gain control in a wireless communication network for power grid control.

BACKGROUND

Wireless networks to be used in the control of power grids, for example in substation automation, require low latency and high reliability. Currently available industrial wireless standards, such as WirelessHART (where HART is short for Highway Addressable Remote Transducer) or Wireless Network for Industrial Automation-Factory Automation (WIA-FA), are not able to provide very high performance in these regards, because they rely on non-optimized physical (PHY) communications layers. For example, WIA-FA is based on the IEEE 802.11g/n PHY layer, whose minimum transmission time for a packet of 100 bits is around 30 μs, while many power grid applications, currently based on wired local area networks (LANs) compliant with IEC 61850, require a slot time of a few μs or even lower.

One cause of the long transmission time in IEEE 802.11 is the use of long preamble sequences at the PHY layer. However, the long preamble in IEEE 802.11 is used for many purposes, including automatic gain control (AGC), which is crucial to ensure reliable message delivery. In this respect, AGC is used in the radio front-end of wireless receivers to automatically tune the gain setting of a variable gain amplifier (VGA) so that the amplitude of the input signal can be adjusted to an optimal level, easing the task of further baseband processing blocks, such as analog-to-digital converter (ADC).

In traditional AGC systems, the gain setting of the VGA is initialized to a nominal value and it reaches the optimal value after a certain amount of time, called settling time. During this time, the AGC processes the first samples of the received preamble, which are discarded afterwards. This procedure is repeated for each packet, since the signals received by different transmitters have considerably different amplitudes.

The duration of the preamble in each packet, hence, cannot be lower than the AGC settling time, fundamentally limiting the achievable latency. In currently available systems, the optimal setting of the VGA gain is performed by using long preambles (e.g. as disclosed in US 20040242177 A1) or out-of-slot dedicated packets (e.g. as disclosed in US 20030091132 A1 and U.S. Pat. No. 5,524,009 A).

Hence, there is still a need for improved automatic gain control in wireless communication networks suitable for in the control of power grids.

SUMMARY

An object of embodiments herein is to provide efficient automatic gain control that does not suffer from the issues identified above, or at least where the issues noted above are reduced or mitigated.

According to a first aspect there is presented a method for automatic gain control in a wireless communication network for power grid control. The wireless communication network employs time based scheduling of packets. The method is performed by a packet receiver in the wireless communication network. The method comprises receiving a packet from a packet transmittter. The packet comprises a preamble. The preamble is composed of a single OFDM symbol. The preamble is represented by a sequence of samples. The method comprises applying automatic gain control to the sequence of samples after variable gain amplitude control has been applied to the sequence of samples. The automatic gain control involves applying an LIT to the sequence of automatic gain controlled samples. The LPF is selected from a bank of LPFs. Which LPF to apply depends on, according to the time based scheduling, from which packet transmitter the packet is received.

According to a second aspect there is presented a packet receiver for automatic gain control in a wireless communication network for power grid control. The wireless communication network employs time based scheduling of packets. The packet receiver comprises processing circuitry. The processing circuitry is configured to cause the packet receiver to receive a packet from a packet transmitter. The packet comprises a preamble. The preamble is composed of a single OFDM symbol. The preamble is 5 represented by a sequence of samples. The processing circuitry is configured to cause the packet receiver to apply automatic gain control to the sequence of samples after variable gain amplitude control has been applied to the sequence of samples. The automatic gain control involves applying an LPF to the sequence of automatic gain controlled samples. The LPF is selected from 10 a bank of LPFs. Which LPF to apply depends on, according to the time based scheduling, from which packet transmitter the packet is received.

According to a third aspect there is presented a computer program for automatic gain control in a wireless communication network for power grid control, the computer program comprising computer program code which, when run on a packet receiver, causes the packet receiver to perform a method according to the first aspect.

According to a fourth aspect there is presented a computer program product comprising a computer program according to the third aspect and a computer readable storage medium on which the computer program is stored. The computer readable storage medium could be a non-transitory computer readable storage medium.

Advantageously this provides efficient automatic gain control.

Advantageously, the proposed automatic gain control does not suffer from the issues noted above.

Advantageously, the proposed method allows an efficient packet structure, enabling low latency wireless communications.

Advantageously, the use of the short preamble enables low latency to be achieved by avoiding the latency caused by the settling time as necessary in traditional AGC systems.

Advantageously, high reliability automatic gain control is still ensured since which LPF to use is selected according to the time based scheduling, dictating from which packet receiver each packet is received.

It is to be noted that any feature of the first, second, third, and fourth aspects may be applied to any other aspect, wherever appropriate. Likewise, any advantage of the first aspect may equally apply to the second, third, and/or fourth aspect, respectively, and vice versa. Other objectives, features and advantages of the enclosed embodiments will be apparent from the following detailed disclosure, from the attached dependent claims as well as from the drawings.

Generally, all terms used in the claims are to be interpreted according to their ordinary meaning in the technical field, unless explicitly defined otherwise herein. All references to "a/an/the element, apparatus, component, means, module, step, etc." are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, module, step, etc., unless explicitly stated otherwise. The steps of any method disclosed herein do not have to be performed in the exact order disclosed, unless explicitly stated.

BRIEF DESCRIPTION OF THE DRAWINGS

The inventive concept is now described, by way of example, with reference to the accompanying drawings, in which:

FIG. **1** is a schematic diagram illustrating a wireless communication network according to embodiments;

FIG. **2** schematically illustrates automatic gain control as used in a packet receiver according to state of the art;

FIG. **3** schematically illustrates a packet structure according to state of the art;

FIG. **4** is a flowchart of methods according to embodiments;

FIG. **5** is a schematic diagram showing functional modules for automatic gain control in a packet receiver according to an embodiment;

FIG. **6** schematically illustrates input amplitudes, output amplitudes, and gain values, according to an embodiment;

FIG. **7** is a schematic diagram showing functional units of a packet receiver according to an embodiment; and

FIG. **8** shows one example of a computer program product comprising computer readable storage medium according to an embodiment.

DETAILED DESCRIPTION

The inventive concept will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments of the inventive concept are shown. This inventive concept may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the inventive concept to those skilled in the art.

Like numbers refer to like elements throughout the description. Any step or feature illustrated by dashed lines should be regarded as optional.

FIG. **1** schematically illustrates a wireless communication network **100** wherein the herein disclosed embodiments apply. Network entities denoted nodes **200***a*, **200***b*, . . . , **200**N are equipped with a radio frequency (RF) front-end that allows them to communicate over a wireless network **110**. Each node may represent a component of a substation automation system, such as a gateway, circuit breaker, circuit protector, transformer, switchgear, etc., that is configured for exchanging control messages.

Each node **200***a*-**200**N may selectively act as a packet transmitter or a packet receiver. Without loss of generality it will hereinafter be assumed that node **200***a* will act as a packet receiver and that any of nodes **200***b*-**200**N will act as a packet transmitter.

FIG. **2** schematically illustrates typical application of automatic gain control in a packet receiver **200***a*. The packet receiver **200***a* employs a feed-back AGC architecture. In this architecture, the amplitude of the signal, V_{OUT}, at the output of the VGA **410** is first measured with a power detector **420**. Then, this value is processed by an AGC **430**, which compares it with a target level and feeds the difference to a low-pass filter (LPF). The LPF drives the gain setting of the VGA **410** so that V_{OUT} converges to the target value after a certain settling time.

The power detector **420** and AGC **430** can be implemented with digital or analog components, depending on the required performance and complexity. Moreover, a feed-forward architecture can be considered, where the input signal, V_{IN}, to the VGA **410** is measured and fed to the AGC **430**.

Regardless of the architecture, in current systems for automatic gain control the gain of the VGA **410** is re-initialized to a nominal target value at each different packet. Indeed, the amplitude of the input signal V_{IN}, and hence the optimal gain required to reach the target value, varies significantly according to the distance between packet transmitter **200***b*, **200***c*, . . . , **200**N and packet receiver **200***a*, the transmitting power, etc. Consequently, each packet comprises an initial sequence of samples that are processed by the system for automatic gain control until convergence is reached after the settling time.

As an illustrative example, FIG. **3** schematically illustrates the packet structure of a packet **300** as used in IEEE 802.11g. The packet **300** comprises a (PHY layer) preamble **310** and a data part **320**. The preamble **310** comprises a legacy short training field (L-STF) part and a legacy long training field (L-LTF) part. In IEEE 802.11g the first short training sequences of the L-STF part of the preamble **310** are used for AGC.

In order to achieve low latency for short-size packets exchanged in wireless networks for power grid control applications, the size of the PHY layer preamble should be kept small, possibly limited to just one single orthogonal frequency-division multiplexing (OFDM) symbol. To preserve a good level of reliability, however, the packet receiver **200***a* must still be able to perform its usual functions, including automatic gain control, using only this single OFDM symbol.

The embodiments disclosed herein thus relate to mechanisms for automatic gain control in a wireless communication network **100** for power grid control. In order to obtain such mechanisms there is provided a packet receiver **200***a*, a method performed by the packet receiver **200***a*, a computer program product comprising code, for example in the form of a computer program, that when run on a packet receiver **200***a*, causes the packet receiver **200***a* to perform the method.

To achieve low latency the packet structure is optimized and a short preamble is used. Further, in order to ensure reliable communications, knowledge of the packet scheduling is used by the automatic gain control mechanism that allows simple and reliable automatic gain control, even when a short preamble is adopted.

FIG. **4** is a flowchart illustrating embodiments of methods for automatic gain control in a wireless communication network **100** for power grid control. The wireless communication network **100** employs time based scheduling of packets. The methods are performed by the packet receiver **200***a*. The methods are advantageously provided as computer programs **820**.

It is assumed that the node acting as packet receiver **200***a* receives a packet **300** from one of the other nodes acting as packet transmitter **200***b*-**200**N. The packet receiver **200***a* is thus configured to perform step S**102**:

S**102**: The packet receiver **200***a* receives a packet **300** from a packet transmitter **200***b*-**200**N.

The packet **300** comprises a preamble **310**. The preamble **310** is composed of a single OFDM symbol. The preamble **310** is represented by a sequence of samples.

Automatic gain control is then applied. The packet receiver **200***a* is thus configured to perform step S**106**:

S**106**: The packet receiver **200***a* applies automatic gain control to the sequence of samples after variable gain amplitude control has been applied to the sequence of samples.

The time based scheduling of packets enables the automatic gain control to rapidly switch between different gain values as soon as a new transmission begins, i.e. as soon as a new packet is received by the packet receiver **200***a*.

Parallel reference is here made to FIG. **5**. FIG. **5** schematically illustrates application of automatic gain control in a packet receiver **200***a* according to embodiments. As the packet receiver **200***a* in FIG. **2**, the packet receiver **200***a* of FIG. **5** comprises a VGA **510**, a power detector **520**, and an AGC **530**. However, the packet receiver **200***a* in FIG. **5** differs from the packet receiver **200***a* of FIG. **2** in the way the AGC **530** is configured.

Specifically, the automatic gain control involves applying (step S**106***b*) an LPF **532** to the sequence of automatic gain controlled samples. The LPF **532** is selected from a bank of LIPFs **532**. Which LPF **532** to apply depends on, according to the time based scheduling, from which packet transmitter **200***b*, **200***c*, . . . , **200**N the packet **300** is received

Embodiments relating to further details of automatic gain control in a wireless communication network **100** for power grid control as performed by the packet receiver **200***a* will now be disclosed.

In some aspects the time based scheduling is based on strict timing synchronization (e.g. time-division multiple access (TDMA)) and is maintained by a central entity (e.g. a network coordinator in the wireless communication network **100**) and distributed among all the nodes **200***a*-**200**N. In this way, each node **200***a*-**200**N knows exactly when it will receive a packet and from which packet transmitter. In FIG. **5** this is illustrated by information from a timing scheduling module **540** being input to the AGC **530**.

In some aspects, and as in the illustrative example of FIG. **5**, variable gain amplitude control is applied by a VGA **510**. Particularly, according to an embodiment the packet receiver **200***a* is configured to perform (optional) step S**104**:

S**104**: The packet receiver **200***a* applies variable gain amplitude control to the sequence of samples, resulting in a sequence of variable gain amplitude controlled samples. The automatic gain control is then applied to the sequence of variable gain amplitude controlled samples.

In some aspects there is one single output value produced by the AGC **530** per received packet **300**. Thus, according to an embodiment, applying the automatic gain control (as in step S**106**) produces one automatic gain control value for the packet **300**.

In some aspects the automatic gain control value is fed to the VGA **510**. Particularly, according to an embodiment the packet receiver **200***a* is configured to perform (optional) step S**108**:

S**108**: The packet receiver **200***a* feeds the automatic gain control value as a control signal. The control signal is to be used during the variable gain amplitude control when applied to a next packet **300** from the same packet transmitter **200***b*, **200***c*, . . . , **200**N.

The automatic gain control value could be fed either as feed-back input (as in the illustrative example of FIG. **5**) or as feed-forward input.

Advantageously, the accuracy of the automatic gain control increases with the **25** number of previously determined automatic gain control values for the same packet receiver **200***b*, **200***c*, . . . , **200**N, Therefore, the use of the LPF **532** ensures that the automatic gain control value converges to its optimum value. This will be further disclosed below with reference to FIG. **6**. The state of the LPF **532** might therefore not be reset after reception of each packet **300**. In this respect, the state of the filter is defined by the K latest-most automatic gain control values for the same packet transmitter **200***b*, **200***c*, . . . , **200**N. Particularly, according to an embodiment the automatic gain control value depends, via the LPF **532**, on a previous automatic gain control value for the **5** same packet transmitter **200***b*, **200***c*, , **200**N. The knowledge of the time scheduling will allow the packet receiver **200***a* to select the appropriate LPF **532** in the of LPFs **532** to update with the just determined automatic gain control value.

In general terms, if the packet transmitter **200***b*, **200***c*, . . . , **200**N and/or packet receiver **200***a* move, the signal strength associated with the received packet might change, thus changing the variable gain amplification and thus the automatic gain control. In some aspects the LPF **532** is therefore reset upon detection of relative movement between the packet transmitter **200***b*, **200***c*, . . . , **200**N and the packet receiver **200***a*. Hence, according to an embodiment the packet receiver **200***b* is configured to perform (optional) step S**110**:

S**110**: The packet receiver **200***a* receives an indication of relative movement between the packet receiver **200***a* and the packet transmitter **200***b*, **200***c*, . . . , **200**N.

There could be different ways for the packet receiver **200***a* to receive the indication of relative movement. In some aspects the indication is received from protocol layers higher than the PHY layer. For example, the indication might be provided as localization information on the application layer.

The packet receiver **200***a* is then configured to, in and in response thereto (i.e., in response to having received the indication in step S**112**) perform step S**114**:

S**114**: The packet receiver **200***a* resets the LPF **532** to a default state, wherein in the default state the automatic gain control value does not depend on any previous automatic gain control value.

As noted above, the state of the filter is defined by the K latest-most automatic gain control values for the same packet transmitter **200***b*, **200***c*, . . . , **200**N. Resetting the filter might thus comprise setting all the K latest-most automatic gain control values as used in the filter to default values.

In some aspects, and as in the illustrative example of FIG. **5**, the AGC **530** comprises at least one comparator **534**. Particularly, according to an embodiment the packet receiver **200***a* is configured to perform (optional) step S**106***a:*

S106*a*: The packet receiver **200*a*** applies applying a comparator **534** to the sequence of variable gain amplitude controlled samples before applying the LPF.

In some aspects the comparator **534** is configured to compare V_{OUT} to target gain value V_N. Particularly, according to an embodiment, applying the comparator **534** (as in step S106*a*) involves comparing the sequence of variable gain amplitude controlled samples to a target gain value. In some aspects the comparator **534** is configured to determine a difference, d, where $d=V_N-V_{OUT}$. The LPF **532** is then applied to the difference, d, resulting from the comparing.

There could be different types of configurations for the comparator **534**. Different embodiments relating thereto will now be disclosed.

In some aspects the AGC **530** comprises one single comparator **534**. Particularly, according to an embodiment one common comparator **534** is applied irrespectively of from which packet transmitter **200*b***, **200*c***, . . . , **200**N the packet **300** is received. This yields a simple implementation (both in terms of storage and use) of the comparator **534**.

In some aspects the AGC **530** comprises a bank of comparators **534**. Particularly, according to an embodiment the comparator **534** is selected from a bank of comparators **534**. This enables the comparators **534** in the bank of comparators **534** to be tailored for different purposes and hence enables a flexible use of different comparators **534** as needed.

There could be different kinds of banks of comparators **534**.

In some aspects there is as many comparators **534** as there are potential packet transmitters **200*b***, **200*c***, . . . , **200**N. Particularly, according to an embodiment, which comparator **534** to apply depends on, according to the time based scheduling, from which packet transmitter **200*b***, **200*c***, . . . , **200**N the packet **300** is received.

In some aspects there is as many comparators **534** as there are types of potential packet transmitters **200*b***, **200*c***, . . . , **200**N. Particularly, according to an embodiment, which comparator **534** to apply depends on from which type of packet transmitter **200*b***, **200*c***, . . . , **200**N the packet **300** is received. That is, there could be one comparator selected if the packet transmitter is a gateway, another comparator selected if the packet transmitter is a circuit breaker, yet another comparator selected if the packet transmitter is a circuit protector, etc.

There could be different ways to implement the selection of which LPF **532** (and which comparator **534**) to use in the AGC **530**. As disclosed above, information from a timing scheduling module **540** is input to the AGC **530**. This input can be used to control switches **536*a***, **536*b*** placed at the input to, and output from, the AGC **530**. Thus, according to the illustrative example of FIG. **5** one switch **536*a*** is placed upstream the bank of comparators **534** and the other switch is placed downstream the bank of LPFs **532**. The switches **536*a***, **536*b*** thus define one example of how enable the appropriate comparator-filter chain to be selected. As is understood, if there is only one single comparator **534**, the first switch **536*a*** is placed between the single comparator **534** and the bank of LPFs **532**. The switches **536*a***, **536*b*** can be implemented through analog or digital components, depending on the required performance and complexity.

An example of the signal amplitudes before and after AGC for a TDMA schedule with M=N−1 packet transmitters is schematically illustrated in FIG. **6**, together with the applied gain values (G). FIG. **6** at (a), (b), and (c) schematically illustrates V_{IN}, V_{OUT}, and G as a function of time, where one packet at a time is received in turn from M packet transmitters according to the time based scheduling. The values of V_{IN}, V_{OUT} are compared to the target gain value.

As can be seen in FIG. **6**, the gain values applied in consecutive packets as received from different transmitters, change significantly, requiring a fast switching process for the AGC. However, in terms of gain values applied to consecutive packets received from a specific packet transmitter the gain values are quite similar, progressively converging to the optimal value according to the LPF behavior (as given by the dash-dotted line in FIG. **6**(*c*)).

FIG. **7** schematically illustrates, in terms of a number of functional units, the components of a packet receiver **200*a*** according to an embodiment. Processing circuitry **210** is provided using any combination of one or more of a suitable central processing unit (CPU), multiprocessor, microcontroller, digital signal processor (DSP), etc., capable of executing software instructions stored in a computer program product **810** (as in FIG. **8**), e.g. in the form of a storage medium **230**. The processing circuitry **210** may further be provided as at least one application specific integrated circuit (ASIC), or field programmable gate array (FPGA).

Particularly, the processing circuitry **210** is configured to cause the packet receiver **200*a*** to perform a set of operations, or steps, **S102**-**S104*e***, as disclosed above. For example, the storage medium **230** may store the set of operations, and the processing circuitry **210** may be configured to retrieve the set of operations from the storage medium **230** to cause the packet receiver **200*a*** to perform the set of operations. The set of operations may be provided as a set of executable instructions.

Thus the processing circuitry **210** is thereby arranged to execute methods as herein disclosed. The storage medium **230** may also comprise persistent storage, which, for example, can be any single one or combination of magnetic memory, optical memory, solid state memory or even remotely mounted memory. The packet receiver **200*a*** may further comprise a communications interface **220** at least configured for communications with at least one packet transmitter **200*a***-**200**N. As such the communications interface **220** may comprise one or more transmitters and receivers, comprising analogue and digital components. The processing circuitry **210** controls the general operation of the packet receiver **200*a*** e.g. by sending data and control signals to the communications interface **220** and the storage medium **230**, by receiving data and reports from the communications interface **220**, and by retrieving data and instructions from the storage medium **230**. Other components, as well as the related functionality, of the packet receiver **200*a*** are omitted in order not to obscure the concepts presented herein.

FIG. **8** shows one example of a computer program product **810** comprising computer readable storage medium **830**. On this computer readable storage medium **830**, a computer program **820** can be stored, which computer program **820** can cause the processing circuitry **210** and thereto operatively coupled entities and devices, such as the communications interface **220** and the storage medium **230**, to execute methods according to embodiments described herein. The computer program **820** and/or computer program product **810** may thus provide means for performing any steps as herein disclosed.

In the example of FIG. **8**, the computer program product **810** is illustrated as an optical disc, such as a CD (compact disc) or a DVD (digital versatile disc) or a Blu-Ray disc. The computer program product **810** could also be embodied as a memory, such as a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM), or an electrically erasable programmable read-only memory (EEPROM) and more particularly as a non-volatile storage medium of a device in an external memory such as a USB (Universal Serial Bus) memory or a Flash memory, such as a compact Flash memory. Thus, while the computer program **820** is here schematically shown as a track on the depicted optical disk, the computer program **820** can be stored in any way which is suitable for the computer program product **810**.

The inventive concept has mainly been described above with reference to a few embodiments. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible within the scope of the inventive concept, as defined by the appended patent claims.

The invention claimed is:

1. A method for automatic gain control in a wireless communication network employing time based scheduling of packets, the method being performed by a packet receiver in the wireless communication network, the method comprising:

receiving a packet from a packet transmitter, the packet comprising a preamble, and the preamble being composed of a single orthogonal frequency-division multiplexing (ODFM) symbol and represented by a sequence of samples;

applying automatic gain control to the sequence of samples after variable gain amplitude control has been applied to the sequence of samples, the automatic gain control involving applying a low-pass filter (LPF) to the sequence of automatic gain controlled samples, the LPF being selected from a bank of LPFs which LPF to apply depends on, according to the time based scheduling, from which packet transmitter the packet is received, and applying the automatic gain control producing an automatic gain control value, the automatic gain control value depending, via the LPF when not in a default state, on a previous automatic gain control value for the same packet transmitter; and

feeding the automatic gain control value as a control signal to be used during the variable gain amplitude control as applied to a next packet from the same packet transmitter.

2. The method according to claim **1**, further comprising:

applying the variable gain amplitude control to the sequence of samples, resulting in a sequence of variable gain amplitude controlled samples, and

the automatic gain control being applied to the sequence of variable gain amplitude controlled samples.

3. The method according to claim **1**, further comprising:

receiving an indication of relative movement between the packet receiver and the packet transmitter; and

in response to receiving the indication, resetting the LPF to the default state, wherein in the default state the automatic gain control value does not depend on any previous automatic gain control value.

4. The method according to claim **2**, further comprising applying a comparator to the sequence of variable gain amplitude controlled samples before applying the LPF.

5. The method according to claim **4**, wherein applying the comparator comprises comparing the sequence of variable gain amplitude controlled samples to a target gain value, and whcrcin the LPF is applied to a difference resulting from the comparing.

6. The method according to claim **4**, wherein one common comparator is applied irrespectively of from which packet transmitter the packet is received.

7. The method according to claim **4**, wherein the comparator is selected from a bank of comparators.

8. The method according to claim **7**, wherein which comparator to apply depends on, according to the time based scheduling, from which packet transmitter the packet is received.

9. The method according to claim **7**, wherein which comparators to apply depends on from which type of packet transmitter the packet is received.

10. The method according to claim **1**, wherein the packet receiver is part of a gateway, circuit breaker, circuit protector, transformer, or switchgear.

11. The method according to claim **1**, wherein the packet transmitter is part of a gateway, circuit breaker, circuit protector, transformer, or switchgear.

12. A packet receiver for automatic gain control in a wireless communication network for power grid control, the wireless communication network employing time based scheduling of packets, the packet receiver comprising processing circuitry configured to cause the packet receiver to:

receive a packet from a packet transmitter, wherein the packet comprises a preamble, wherein the preamble is composed of a single orthogonal frequency-division multiplexing (OFDM) symbol and represented by a sequence of samples;

apply automatic gain control to the sequence of samples after variable gain amplitude control has been applied to the sequence of samples, wherein the automatic gain control involves applying a low-pass filter (LPF) to the sequence of automatic gain controlled samples, wherein the LPF is selected from a bank of LPFs, wherein which LPF to apply depends on, according to the time based scheduling, from which packet transmitter the packet is received, and wherein applying the automatic gain control produces an automatic gain control value, the automatic gain control value depending, via the LPF when not in a default state, on a previous automatic gain control value for the same packet transmitter; and

feed the automatic gain control value as a control signal to be used during the variable gain amplitude control when applied to a next packet from the same packet transmitter.

13. The packet receiver according to claim **12**, wherein the processing circuitry is configured to cause the packet receiver to:

receive an indication of relative movement between the packet receiver and the packet transmitter; and

in response to receiving the indication, reset the LPF to the default state, wherein in the default state the automatic gain control value does not depend on any previous automatic gain control value.

14. The packet receiver according to claim **12**, wherein the processing circuitry is configured to cause the packet receiver to:

apply the variable gain amplitude control to the sequence of samples, resulting in a sequence of variable gain amplitude controlled samples, and

wherein the automatic gain control is applied to the sequence of variable gain amplitude controlled samples.

15. The packet receiver according to claim **14**, wherein the processing circuitry is configured to cause the packet receiver to apply a comparator to the sequence of variable gain amplitude controlled samples before applying the LPF.

16. The packet receiver according to claim 15, wherein the processing circuitry configured to cause the packet receiver to apply the comparator comprises:

the processing circuitry configured to cause the packet receiver to compare the sequence of variable gain amplitude controlled samples to a target gain value; and

wherein the LPF is applied to a difference resulting from the comparison.

17. The packet receiver according to claim 15, wherein the processing circuitry is configured to cause the packet receiver to apply one common comparator irrespectively of from which packet transmitter the packet is received.

18. The packet receiver according to claim 15, wherein the processing circuitry is configured to cause the packet receiver to select the comparator from a bank of comparators.

19. The packet receiver according to claim 12, wherein the packet receiver is part of a gateway, circuit breaker, circuit protector, transformer, or switchgear.

20. A non-transitory computer readable medium storing a computer program for automatic gain control in a wireless communication network for power grid control, the wireless communication network employing time based scheduling of packets, the computer program comprising computer code which, when run on processing circuitry of a packet receiver, causes the packet receiver to:

receive a packet from a packet transmitter, wherein the packet comprises a preamble, wherein the preamble is composed of a single orthogonal frequency-division multiplexing (OFDM) symbol and represented by a sequence of samples;

apply automatic gain control to the sequence of samples after variable gain amplitude control has been applied to the sequence of samples, wherein the automatic gain control comprises applying a low-pass filter (LPF) to the sequence of automatic gain controlled samples, wherein the LPF is selected from a bank of LPFs, wherein which LPF to apply depends on, according to the time based scheduling, from which packet transmitter the packet is received, and wherein applying the automatic gain control produces an automatic gain control value, the automatic gain control value depending, via the LPF when not in a default state, on a previous automatic gain control value for the same packet transmitter; and

feed the automatic gain control value as a control signal to be used during the variable gain amplitude control when applied to a next packet from the same packet transmitter.

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